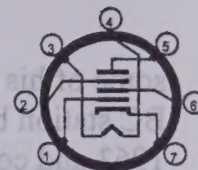
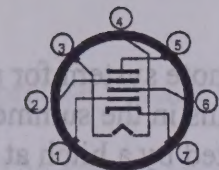


# HOLLOW STATE NEWSLETTER

"For lovers of vacuum tube radios"

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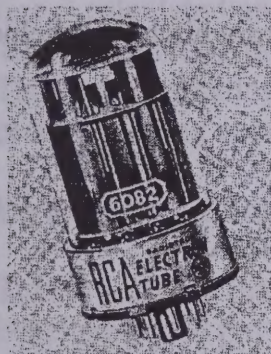
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## **SOLID STATE VOLTAGE REGULATOR MOD FOR THE R-390/391**

**By Dr. Gerald N. Johnson, K0CQ**

## **Editor's Introduction**



The R-390 was the original version with a beefier gear train, L/C IF's (no mechanical filters), higher tube count and more elaborate power supply, to name a few differences vs. its offspring, the R-390A. One of those differences is a pair of 6082 voltage regulator tubes. They're impressive-looking, however, these tubes are becoming more scarce -- and expensive. They also produce a great deal of heat, and in their upside-down position, it rises and concentrates in the AF deck. They have been notorious for "cooking" components as well as contributing considerably to the overall temperature level in the receiver.

While it would seem to be counter to the mission (and masthead) of this publication, a solid state replacement is actually in the interests of preservation of both the radio and remaining supplies of 6082's. It would be nice to have an easily done and reversible modification.

Some months ago, I acquired an R-391 with a heavily solid stated AF deck. (The R-391 has mechanical autotune, but is electronically identical to the R-390 non-A.) Both the audio and power supply circuitry had been subbed out. The audio was now handled by a small module under the deck and a solid state circuit on a piece of perfboard replaced the 6082's. This was not done in a reversible way, so the particular physical layout of the "prototype" is not presented here.

I reported this discovery on the R-390 reflector list. Coincidentally, Dr. Gerald Johnson had been designing a VR circuit on paper. He had no R-390/391 to use as a test bed. I had the gear, but not the know-how to analyze the circuit I found. So, we worked together, tethered by e-mail, with your editor acting as technical assistant.

Many of you know Dr. Gerald Johnson from the QTH reflector lists. Jerry has a BSEE, Washington University (St. Louis) 1963, an MSEE (1967), and PHd (1976) both from Iowa State. Dr. J. earned



some of his undergraduate expenses fixing radios and TVs. He built a mobile remote system for a BC station before starting work in the high power transmitter department at Collins in the summer of 1963 and continued the next year at Richardson. His graduate work was interrupted by a hitch at the Army's Night Vision Laboratory. "Dr. J." has been working as a self-employed consulting engineer since 1970. His work has varied from lighting to accident and fire analysis to radio design to software creation.

Jerry was first licensed KN0CQA at age 13, in 1955, general (K0CQA) the next year, then amateur extra ('58) and became K0CQ in 1976. As for "hollow-statesmanship", in addition to an R-390A, he has a Wilcox fixed frequency HF receiver for WWV, an Instrument Corporation of Florida VLF receiver for WWVB, a Heathkit SB-110A, Collins 75S3B and 32S1 with home brew power supply and an HP 608F signal generator, as well as other tube type test equipment still in use. He uses a tube amplifier on 70 cm and has others under construction. Most of his Collins work was on tube 250 KW AM transmitters for VOA. Last year, Jerry built a voltage regulator for the lighting turbine on a steam locomotive. (Now THERE's a true BOAT ANCHOR! Built new in China in 1988, it's younger than most radio BOAT ANCHORS - K0CQ).

Jerry says: "The ham licenses drove the education, the work (except for an army hitch) just helped pay for hamming."

### A Solid State Voltage Regulator for the R-390 (non-A)

**Dr. Gerald N. Johnson, K0CQ**

A few months ago, Barry Hauser acquired an R-391 with a solid-stated power supply and recalled that I had been tinkering on paper with a suitable circuit to replace the 6082's. There was no documentation and the mod was done by someone unknown to the previous owner. As a first step in collaborating by e-mail, Barry drew up a schematic of what he found and sent it to me, the first step in this "reverse-engineering" project.

The regulator circuit we found is a Darlington-connected emitter-follower running off a zener reference, kind of hammer and tongs -- no feedback other than that inherent in the emitter-follower. I don't have a high regard for high voltage zener diodes. I would expect to see variations in output voltage from changes in unregulated supply voltage and load current. The zener diode has a soft knee so that changes in zener current cause changes in voltage. Also, the load current variations would affect the drop between the zener-regulated base and the emitters, probably leading to a half-volt change just from over-varying load currents. I'd have thought the original tube regulator would have better performance with feedback using the VR tube as the sample reference and better voltage stability with current variations than the zeners. At that point the decisions have to be biased according to what the radio really needs, i.e., is the main function here an electronic ripple filter or i.



precise voltage regulation also necessary?

The circuit, shown in Fig. 2, had apparently been done some years ago and identifying the components proved to be somewhat tentative. The transistors in the unit as found are probably Japanese parts 2SC3039 and 2SD1398, likely made for TV horizontal output stages. We found two zeners in parallel, which could be identical values. I wouldn't think they'd have to dissipate a lot of power to justify the use of two. Further, lowering current to them doesn't help the regulation, so I don't agree with that part of the design.

After I more thoroughly analyzed the circuit "as found", it computed to be adequate. That 100K resistor acts a lot like a current source with about 100 volts drop across it and the slope of the zeners and their series resistors doesn't make the voltage change unreasonable.

My calculations told me that -- if the zener diodes are truly 180 volts -- with a 105 volt AC supply, the unregulated will be 265 and the regulated will be 180.344 volts. With 117, (presumably normal line voltage) unregulated will be 295 v. and regulated will be 180.868 v. Finally, with a 125 volt line, I calculated unregulated and regulated will be 315 v. and 181.25 v., respectively. Not at all bad! That's neglecting the base current of the driver transistor and temperature effects on the zener diodes. They are dissipating a total of about 180 milliwatts so are probably running fairly cool. One is probably doing nearly all of the work because their voltages probably are not precisely the same.

### Performance Comparison & Specs:

This brought up the need for some empirical testing. Barry had a stock R-391 handy to use as a benchmark and put out a call for assistance on the R-390 e-mail reflector for other R-390/391 owners with a variac and voltmeter handy.

We varied the line voltage from 95 VAC up to 125 VAC in 5-volt steps and measured the B+ at each, monitoring the AC voltage with a meter. The solid state circuit performed comparably to all but one Motorola-built R-390 which, for some reason, far exceeded specs.

The Darlington circuit showed a delta of +0.4 -0.6 from the 110 volt input value. The original R390 design specification was +/- 1 volt. The solid state regulator did a delta of 1.0 volts. My second zener mod will make the solid state version do better.

In my search for operating specs, I found the following on typed page 14 of the engineering report, which is posted on the R-390A FAQ site:

"Early in the program a B+ current requirement of 125 ma was estimated and the first power supply circuits were built accordingly. As the equipment was developed more and more current was required until the last models ended up using about 200 ma. The supply shown will deliver 200 ma at 180 volts with excellent regulation and low ripple content as the following data indicates:



Input voltage variation of  $\pm 15\%$  B+ variation  $\pm 1$  volt maximum

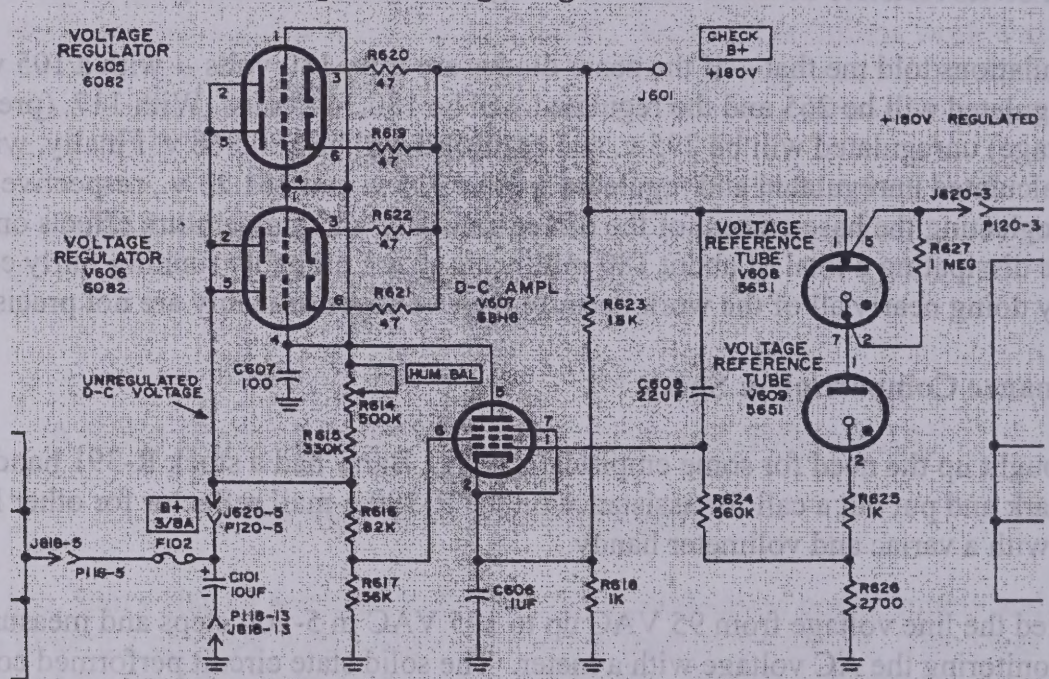
Load current variation 100 to 200 ma B+ variation  $\pm 2$  volt maximum

Ripple voltage normal 0.01 volts

Ripple voltage worst condition 0.1 volts"

So, the simple zener/Darlington supply basically meets the R-390 engineering specifications.

**Figure 1**  
**Original Voltage Regulation Circuit**



## CONSTRUCTION:

### Component selection:

The circuit as found uses transistors that were available to the builder at the time and would be difficult to find now. However, there are many other components that will work.

Q1 has to handle 350 volts, dissipate 3 or 4 watts and pass probably under 20 milliamps. That takes a TO-220 package or TO-3. The device will have 300 volts on the tab, if not an insulated tab or suitably enclosed TO-220, Motorola 221D-01, UL File E69369), or TO-0247 or TO-3PBL.

Q2 needs the same case options and voltage and has to dissipate 25 to 30 watts and carry 200



milliamps. (See the ENHANCEMENTS / REFINEMENTS section for a way to reduce the power dissipation of the transistors.)

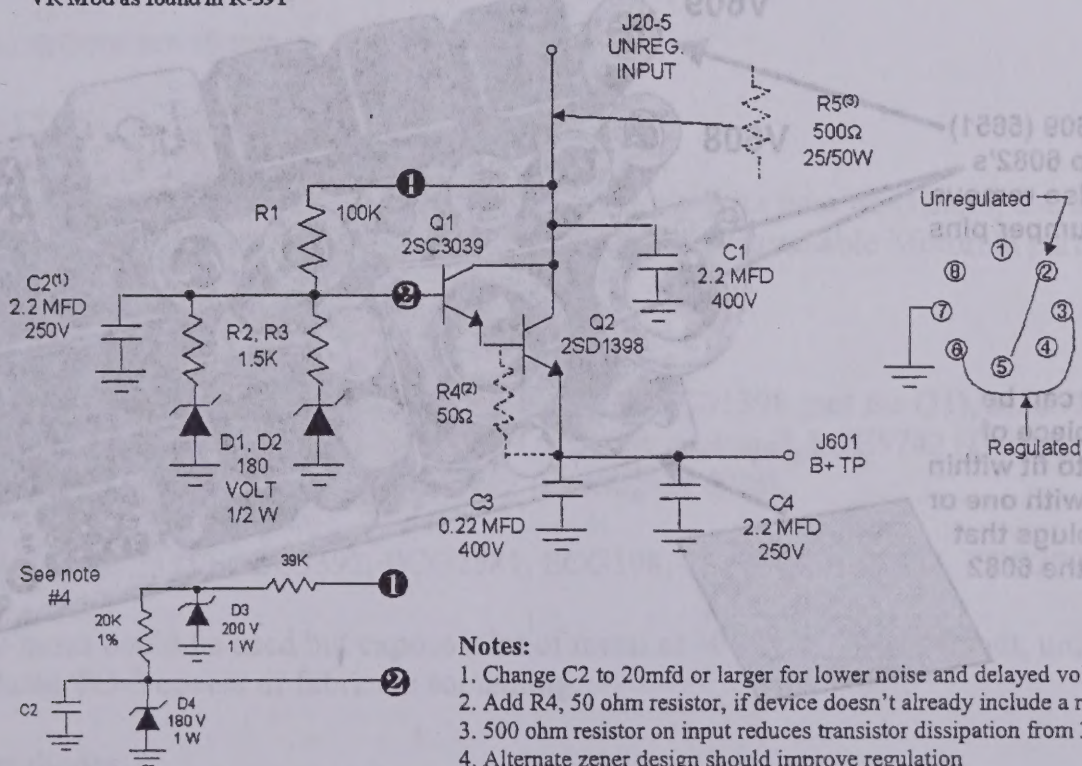
Thus, the needs of Q1 and Q2 can be met by most any transistor that can handle a few amps and more than 350 volts in a TO-220 or isolated package. Both can be the same type. The original 2SD1398 included a 50 ohm resistor from base to emitter and a clamp diode from collector to emitter. The resistor would be a bother in Q1 causing poorer regulation. If not present in Q2, a resistor (R4 on the schematic) with value between 500 ohms and 2K should be there to divert leakage from the input of Q2. In this circuit, the clamp diode is of no benefit, but it won't hurt anything either.

The 2SC3039 is a 400 volt, 100 w, 12A NPN transistor, the 2SD1398 is a horizontal output / damper transistor, 800 volts 5 A, 120 watts with a 50 ohm resistor base to emitter and a diode from emitter to collector.

- Use a 180 volt 1 watt zener diode, no series resistor.
- The 0.22 should be paper, the 2.2 and larger would probably be electrolytic.
- The transistors need a large-enough heat sink to dissipate 5 watts continuously.

**Figure 1**

VR Mod as found in R-391





## Construction Approaches:

I prefer using an octal plug (or one harvested from a bad tube), or two – one for each 6082 socket, to parallel all the cathode pins to reduce the resistance after the regulator. This eliminates the need to pull the module from the radio to install the regulator, or switch back for that matter. Just pull the two 6082's and the VR tube (V609) and plug in the solid state regulator assembly. V608 may also be removed, however you'd need to jumper pins 1 and 5 of that socket to provide power to the oscillators. (V608 won't draw any current with V609 removed.) If using a single octal plug, the assembly could be arranged to cover the second 6082 socket, if there's a concern about someone stuffing in a tube. As the signal is DC, the builder can use long leads to position the regulator above the radio in the corner of the cabinet to effectively move heat out of the radio. If going this route, it's important to make sure that the regulator transistors are insulated from contact and the heat sink is grounded. You may be able to find the plastic caps frequently found on rear panel mounted TO-3's. Otherwise, a small piece of fiberglass or phenolic board can be mounted on non-conductive standoffs just over the cases to prevent accidental contact.

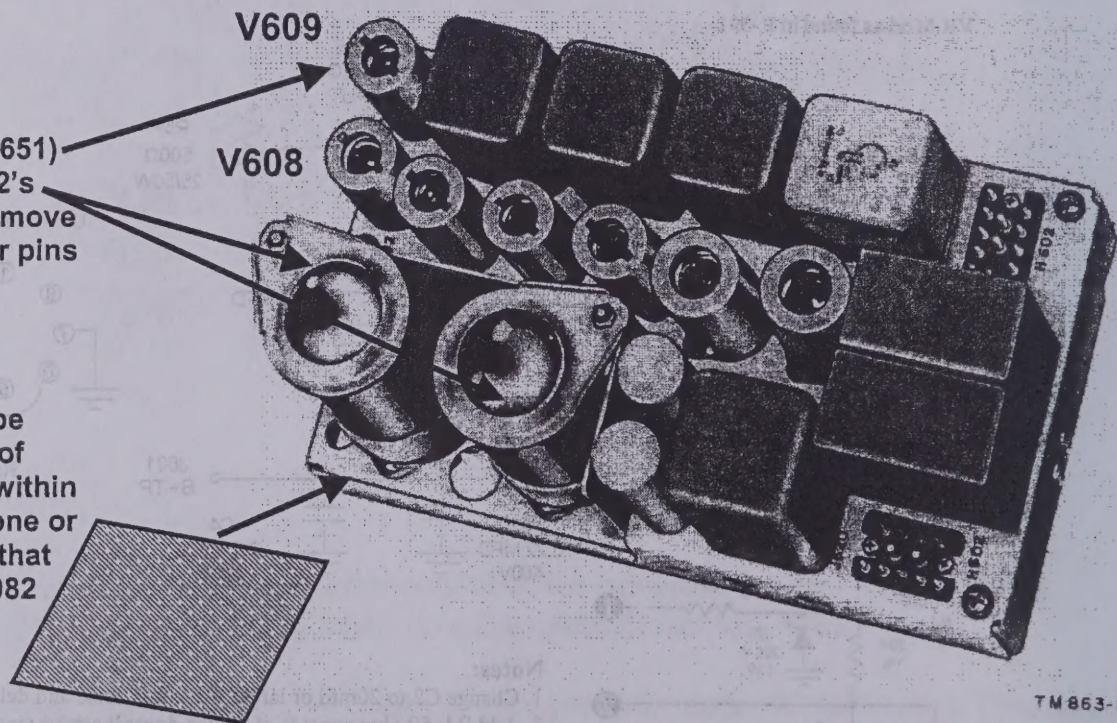
Remember 300 volts DC BITES!

Pull the other 6082 and the 5651 and leave the 6BH6 to supply heater power to audio tubes.

Fig. 2

Remove V609 (5651) and the two 6082's. You may also remove V608 and jumper pins 1 and 5.

The circuit can be built on a piece of perfboard to fit within the shield with one or two octal plugs that mate with the 6082 sockets.



I think its best to move the regulator out of the bottom of the radio on a cable. That would remove about 50 watts of heat from the underside of the mainframe -- 25 watts from plate dissipation and 25 watts of heater power. The PTO and crystals would benefit from the heat reduction.



## ENHANCEMENTS / REFINEMENTS

First, the paralleled zener diodes with current sharing resistors gain nothing over a single 180 volt 1 watt zener diode.

Second, a capacitor across the zener reference would reduce noise contributions of the zener AND cause the DC to rise with a  $100K * C$  time constant. This would be a gentle rise, more like that of the 26Z5 heater/cathode rectifiers than the solid state rectifiers. Some are concerned about the B+ appearing far more rapidly than the tubes heat up. That fast B+ could have a barely detectable effect on tube life, probably occasionally leading to cathode surface damage from the early B+ forcing plate current from a cold emitter. So the capacitor can calm that concern while lowering the zener induced noise.

Third, a 375 to 500 ohm 25 or 50 watt resistor in the power transistor collector circuit moves power dissipation from the pass transistor and driver to that resistor which handles the heat better. This makes for easier heat sinking and lower-temperature transistor operation.

Fourth, using two zener diodes, one 180 volt and one 200 volt, with the 180 volt zener reference supply regulated roughly by the 200 volt zener, should significantly improve the line voltage regulation.

These options are shown on the schematic, Fig. 2.

## PARTS

There are probably 15 or 20 ECG parts that would work for pass transistors, and at least a couple of ECG/NTE zener possibilities and several times that many available Motorola parts.

Potential part numbers for Q1 and Q2 include:

TIP50, BUX85, MJE13005, MJE18204, 2SC3039, 2SD1398 (not for Q1), MJE5740 (Darlington transistor that might replace both Q1 and Q2 in one package), MJE5742 (Darlington ditto), MJE13007 (Darlington ditto), MJH10012 (Darlington ditto),

BUV48A, 2SC4953, 2SC5392, ECG2581, ECG198, ECG51, ECG2312, ECG379

TO-3 cases could be used but expose a lot of metal at 300 volts. I'd rather not, unless you can find insulated TO-3 covers or fabricate something.

Zener diodes:

180 volt:

1N5279B, ECG5058A 1/2 watt; 1N3050, ECG5103A 1 watt; 1N5955A, 1N3819 1.5 watt



Microsemi (Digi-key) 2EZ180D5 2 watt; 1N5386B 5 watt

200 volt

1N5281B, ECG5060A 1/2 watt; 1N3051, ECG5105A 1 watt; 1N5956A, 1N3820 1.5 watt

Microsemi (Digi-Key) 2EZ200D5 2 watt; 1N5388B 5 watt

As far as I know, NTE and ECG numbers are the same but it no longer matters as NTE has bought out ECG.

Heat sink:

IERC 7-339-4PP-BA for TO-220, 17 watts; ECG440C, ECG440D

Thermally conductive insulator: ECG425E

### Editor's Wrapup:

All in all, this is a worthwhile little project that can go a long way toward preserving your R-390. We'd be interested in hearing from anyone who builds a new circuit with currently available parts. I'd like to do a follow-up article. Many thanks to Jerry for all his fine work. If there are any questions, you may contact him by email at [geraldj@isunet.net](mailto:geraldj@isunet.net), or by mail through the editor.

### Request for Contributions:

If you would like to contribute an article, please contact me at [barry@hausernet.com](mailto:barry@hausernet.com) or the postal address on the masthead

WTB - Complete and fully functional R-390/URR with instruction manual. Contact C6AN1, P.O. Box N4106, Nassau, NP, Bahamas

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